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Installations options for the NAVSTAR Global Positioning System in surface ships

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THESIS

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GLOBAL POSITIONING SYSTEM IN SURFACE SHIPS

by

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This thesis compares three alternative methods of completing this installation program: 1) installation during a ship's regularly scheduled overhaul, 2) installation by a special team of technicians, and 3)

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Installation Options for the NAVSTAR Global Positioning System in Surface Ships

by

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Lieutenant United States Navy
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I. INTRODUCTION

Whenever a new system is developed for operational use there are decisions that must be made regarding the introduction of the system. One of the most critical is the method that will be used to introduce the new system to operational units. Regardless of the value of a system itself, it is useless, unless its capabilities can be used by operational units. This problem becomes particularly difficult when the new system must be retrofitted on existing platforms. Consideration must be given to the method of retrofit, will a combat unit be removed from an operational status for the retrofit, or will the new system be installed while the unit continues in an operational status.

Decisions made regarding the installation will not only affect the operational forces but will influence the procurement rate for the new system, determine the manpower requirements for system installation and maintenance, and the rate of the introduction of the new capability.

The NAVSTAR Global Positioning System (GPS) is a new navigational system. This system is scheduled for use in a wide variety of situations. The GPS will be used by all military services to provide positioning information to combat and support units. There are three different models of the GPS receiver. The existence of these three models allows the system to be used by all types of military forces, from foot soldiers to supersonic aircraft.

The GPS is scheduled to be installed in all US Navy ships, commencing in 1989. The method that will be used for this installation has not yet been determined. There are three main alternative methods for accomplishing this

planned installation. They are: 1) installation during a ships regularly scheduled overhaul, 2) using a special installation or tiger team, 3) utilizing the skills availible in the ships company. Each method has advantages and disadvantages. With the scheduled installation date rapidly approaching the determination of the method to be used for installation must be made soon.

This decision will be made by Commander Naval Sea Systems Command based on the recommendation of the Joint Program Office.

This thesis will examine these three alternative methods of installation. The relative costs and the potential advantages and disadvantages of each method will be explored. The goal is to provide a recommended method of installation of the Global Positioning System in US Navy surface ships.

Regardless of the installation method that is used for the majority of ships there will be special circumstances or requirements, Ships whose installation priorities are so high that cost and schedule requirements will be of secondary importance. These ships will have the system installed in the quickest manner and are therefore not addressed herein.

The determination of the installation method for the GPS will determine the costs that will be experienced, and thereby the funding profile needed to support the installation. The method chosen will also determine the schedule that must be followed. The different methods will experience different rates of installation and they will provide differing amounts of flexibility. Since these alternatives will provide differing installation rates, they will pose different demands on the production schedule. They will also require differing numbers of technicians to support the GPS.

The desire to introduce the system as quickly as possible must be balanced against the planned production schedule. The need to hold costs to a minimum must be weighed against the needs of the fleet for the GPS. These needs and the effects of the system introduction on the manpower avialable to the Navy must be considered by the Joint Program Office in making their recommendation for the installation method. The planning schedule currently in use is reflected in the Program Objective Memorandum 1986 (POM 86) [Ref. 1]. This schedule is based on the use of the tiger team installation method. The costs reflected in this schedule were determined using the Shipboard Electronics Equipment Installation (SEESTALL) cost estimating model. This model was develcped by the ARINC Reasarch Corporation of Annapolis Md, for Commander Naval Sea Systems Command [Ref. 2].

A. METHODOLOGY

There is limited available documentation concerning the installation options for the GPS. Accordingly the method of research utilized in this thesis is primarily the personal interview. This thesis collects the applicable knowledge of numerous people throughout the United States. The majority of the technical installation information was provided by the personnel at the Joint Program Office for the GPS program in Los Angeles and the Naval Electronics Systems Engineering Center in San Diego California.

Analysis and conclusions are based on the authors understanding of statements and comments gathered through interviews and telephone conversations. The analysis and conclusions are the result of interpretations of the information availible within the research time frame.

Judgements and analysis of the author reflects and is based on his personal experience as a Surface Warfare Officer, which includes a regular overhaul as a member of ships company.

This thesis is primarily directed to those readers who are familiar with the GPS program and system. If further background information regarding the GPS is required refer to reference 3.

B. THESIS ORGANIZATION

Chapter two provides a summary of the significant events in the history of space based navigation systems and discusses the NAVSTAR GPS components.

Chapter three examines the general problems that will be encountered regardless of the installation method.

Chapter four examines the overhaul method of installation, the tiger team method is examined in chapter five, and chapter six examines the ships force installation.

Conclusions and recommendations are presented in chapter seven.

II. BACKGROUND AND SYSTEM DESCRIPTION

The NAVSTAR Global Positioning System (GPS) is a highly accurate satellite based positioning and navigation system. GPS has been under development since 1973. It is a joint program, with the Air Force acting as the lead service. The system provides three dimensional positioning (latitude, longitude, and altitude), velocity, and time information to its users.

The GPS is not the first space based navigation system. The idea has been developed over several decades. The impetus for the space based system has been the desire for a highly accurate navigational system that could meet the needs of a broad spectrum of users.

The Navy initiated the Navy Navigational Satellite System (TRANSIT) in 1958. This system was primarily intended to provide navigational information to Fleet Ballistic Missile submarines. This system became operational in 1964. The Navy also sponsored TIMATION, a research program to advance the development of high stability oscillators, time transfer, and two dimensional navigation. Concurrently the Air Force conducted preliminary concept formulation and system design studies for a three dimensional navigation system called the system 621B.

In 1973 the Deputy Secretary of Defense directed combination of these research efforts. The Air Force was designated as the Executive Service to coalesce the concepts into a single comprehensive, Department of Defense system. This reduced the duplicative design effort and has reduced the Government expense by producing one system that meets all needs rather than producing several service specific systems.

A. SYSTEM DESCRIPTION

To provide navigational information the GPS uses three major segments, the space segment, the control system segment, and the user system segment.

The space segment includes a navigation package and an integrated operational nuclear detonation detection system. For full operation this segment requires 18 satellites in 6 orbital planes 10900 nautical miles above the earth. In addition, back up satellites will be placed in orbit to ensure 100% system availability in event of satellite failures. Current plans call for the satellites to be launched by the Space Shuttle.

The control system segment consists of a master control station, three ground antenna stations, and five monitor stations to maintain control and accuracy of the satellites.

The user system segment consists of one of three types of receivers which process the satellite data to determine position, velocity, and time. To determine this information the receiver gathers ranging data from four of the 18 satallites in orbit. It then can compute position to within 16 meters, velocity to 0.1 meters per second, and time to 100 nanoseconds. The type of receiver used depends on the requirements of the host vehicle. While stationary all sets perform with equal accuracy. The low dynamic set is a one channel receiver. It gathers ranging data from each of the four satellites required for the solution of the navigational problem sequentially. Because the information is gathered sequentially the receiver is more affected by platform movement. If platform velocity exceeds 25 meters per second (approximately 50 knots) the one channel receiver cannot select the four satellites fast enough to solve the navigational problem. This receiver is scheduled to be used in the manpack and in vehicles. The medium dynamic set is a

two channel receiver. It gathers ranging data from two satellites simultaneously then selects two others to obtain the four required for the solution of the navigational problem. The two channel receiver is limited to a platform velocity of 400 meters per second (approximately 775 knots) or less. The two channel receiver is scheduled to be installed in ships, patrol aircraft, transport aircraft, and helicopters. The high dynamic receiver has five channels. It gathers ranging data from all four satellites required for positioning data simultaneously. This provides essentially real time positions. The five channel receiver is scheduled for installation in submarines, fighter, bomber, and attack aircraft.

As the capability of the receiver increases the price increases. This is one of the main reasons that the five channel set is not scheduled for use in all applications.

The Air Force awarded a single source, multiyear procurement contract on a fixed price incentive basis to the Rockwell International Corporation in May, 1983 for the production of the GPS spacecraft and related equipment. In September 1980, the Air Force entered a firm fixed price contract with the International Business Machine (IBM) Corporation to develop the control segment.

The contract for manufacture of the receivers has not yet been awarded. There are currently two competing receiver designs undergoing full scale development. The competing manufacturers are Magnavox Advanced Products and Systems Company of Torrance California, and the Rockwell International, Collins Government Division of Cedar Rapids Iowa. The Defense Systems Acquisition Review Council milestone III reveiw (DSARC III) for production of the receiver system is currently scheduled for early 1985.

These two competing designs are different in appearance but they have the same basic components and are of similar

size and weights. Complete descriptions of all components may be found in reference 3.

III. INSTALLATION PLANNING

The GPS is scheduled for installation in a wide variety of military vehicles. The medium dynamic set is scheduled for installation in all US Navy surface ships between 1989 and 1996. [Ref. 1]. GPS will provide these ships with a highly accurate all-weather navigation system that is currently not available. It will replace the Navy Navigational Satellite System currently in use aboard some ships. GPS will expand the satellite navigation system to all Navy ships, replacing less accurate radio based systems such as OMEGA and Loran as the primary electronic navigation systems.

A. POTENTIAL PREINSTALLATION PROBLEMS

There are three preinstallation problems that will be present regardless of the installation method that is chosen, they are: Long lead time item procurement, secure storage, and the evolution of the navy electronics suite.

Several of the connectors and much of the cabling that is used in GPS installation are long lead time procurement items. These items require advance planning in ordering to ensure that sufficient stocks are on hand when installation begins. Time between placement of the order and receipt can be in excess of one year. These long lead items are especially critical if the installation is to be conducted during regular overhaul. If a ship does not receive GPS during the specified overhaul, because of the unavailability of parts, it will be about five years before that ship enters overhaul again. This delay could force some ships to have the GPS installed in an alternate method to remain

within the desired installation time window. Unavailability of parts would also affect the scheduling of the other installation methods, although not as drastically.

Related to the problem of long lead times is one of storage. There are currently no dedicated GPS storage facilities. Either special storage must be constructed, or it must be arranged through Naval Supply Centers. The long lead items in particular and the GPS equipment in general must have secure storage so that when an installation commences all required items will be availible. One central warehouse would provide ease of control over the supplies, and ease reorder decisions because the exact quantity on hand would be known. On the other hand several dispersed storage facilities would provide faster service to the installation in progress and lower shipping costs because of shorter distances involved.

The uncertainty of design evolution of the Navy electronics suite is a concern because the GPS must interface with several key electronics systems, such as the Naval Tactical Data System. As the systems that GPS interfaces with are modernized care must be taken to ensure that no changes make the system incompatible with GPS.

B. POTENTIAL INSTALLATION DIFFICULTIES

There are also three installation problems that must be addressed regardless of the method chosen. They are interfacing with shipboard systems, drawing inaccuracies, and differences between ships of the same class.

The first problem is interfacing with other shipboard equipments. The GPS will interface with a variety of systems such the Naval Tactical Data System (NTDS), Carrier Navigation System (CVNS), the gyrocompass and the electromagnetic log. The design of the GPS receiver system is not

firm enough at this point in time to plan the method of interface. There are currently two possible methods. The first method of interfacing is through a Flexible Module Interface (FMI). The FMI would be uniquely designed for each specific requirement. This entails a separate design for each different ship type, with the design depending on the electronic configuration of each ship. This approach has the potential of becoming very expensive. Because of this potential expense this currently appears to be the less likely approach. The alternative to the FMI is the fixed FMI or serial data ports. These ports would provide a standard output which would then be used to interface with any shipboard system. A common interface unit is planned for follow on production. This common interface will simplify installation in the later years. Until the method of interfacing is determined exact installation plans can not be made.

A second problem is the lack of accurate drawings or blueprints for all ships. Major changes are normally reflected, in the blueprints, however, over time changes made to the ships have not been reflected in the drawings. Taken individually the effect of each of the unreflected changes is insignificant, in total they may cause problems. During the installation of GPS in the USS Kitty Hawk several problems were encountered with inaccurately labeled interior communications switchboards (used in interfacing with the gyrocompass and the electromagnetic log) and many problems resulted from drawing inaccuracies regarding bulkhead penetrations. This problem is amplified on an installation as large as a carrier. Each new penetration requires special care to ensure that the watertight integrity of the ship is not reduced. Problems such as these lengthen the planning stage by making physical ship configuration checks mandatory for all ships before any wiring plans can be drawn. The

time between the ship check and the actual installation must be held to a minimum, or location and space for equipment decided on during the configuration check may be used for another purpose and not be available. On the Kitty Hawk problems were encountered because bulkhead penetrations marked for GPS installation during the ship check were used for another purpose before the installation began.

The third major problem is that ships of the same class are seldom identical. The GPS signal is below the background noise level. For the receiver to have sufficient signal strength for determining position information the antenna must be relatively free of electromagnetic interference (EMI) from other shipboard equipment. To ensure no significant EMI is present the antenna position for the GPS must often vary. The correct placement of the antenna again requires a ship configuration check.

C. INSTALLATION REQUIREMENTS

The actual installation of the basic GPS receiver is fairly simple. The components of the receiver system are all light and compact enough so that movement by hand is possible. The heaviest component is the Master Control unit which weighs 130 pounds. Movement of components can be simplified through the use of a crane, also, antenna placement is easier with a crane but not required. The antenna weighs 20 to 30 pounds depending on the model that will be ultimately selected. The most difficult material handling problem is the cabling. For the most extensive interfaces the cabling required is 64 wire cable. The weight of this cable is approximately 10 pounds per foot. Movement of this cable from the pier to the ship will require a crane.

The primary skills required for the installation process are: electronics technician, interior communications

specialist, and shipfitter. The skill levels are roughly equivilent to GS-11 for the electronics technician, WG-10 for the interior communications specialist, and WG-9 for the shipfitter [Ref. 4]. The number of personnel required depends on the size of the ship, the length of the required cable runs and the number of interfaces. The team required for an aircraft carrier is about 12 people [Ref. 5].

D. GPS PROTOTYPING IN SURFACE SHIPS

GPS has been installed in and then subsequently was removed from the USS Kitty Hawk (CV-61). The installation was conducted as a two phase process. The cabling and the foundation work was installed during regular overhaul by The Naval Shipyard Bremerton. The final system installation was conducted by Naval Electronics Systems Engineering Center, San Diego.

Planning is currently being done for the installation aboard the USS Constellation (CV-64). Installation will be done by the MDS Company during regular overhaul.

Since these ships were part of the testing process within the full scale development (FSD) phase, neither the Kitty Hawk nor the Constellation installations fit exactly in one of the three methods outlined earlier. It is possible however, to use the experience gained in these installations to identify potential problems that may arise during future installations. They also provide a basis for estimates regarding installation time, costs and skills required. The SEESTALL model [Ref. 2] and planning data prepared for the Constellation has been used as the base for cost comparisons expressed herein. Experience from the Kitty Hawk test installation has been used to highlight potential problems during the planning for the actual installations.

At this writing plans for development do not include further prototype testing on surface ships. By evaluating the GPS on a carrier where the most complex electronic environment in a surface ship exists it is believed that any potential problems will be discovered [Ref. 6]. Although no further prototyping is intended the first ship of each class to receive the GPS will undergo special testing. This testing will be to ensure that the installation on that particular class of ship is satisfactory. Then all other installations for ships of that class will follow the same basic installation plan [Ref. 7].

IV. SHIPYARD INSTALLATION

A. SHIPYARD CAPACITY

The U.S. Department of Transportation Maritime Administration conducts annual surveys of the shipbuilding and repair facilities in the United States. The survey for 1983 [Ref. 8] reports that there are currently 587 shipbuilding ways in excess of 475 feet, and 139 repair facilities with berths in excess of 300 feet. These facilities do not include Naval shipyards which would increase the capacity even further. There is sufficient civilian capacity available to place all Navy ships scheduled to receive GPS in a special yard period at one time. This is of course inconsistant with the with requirements for the defense of the nation, but it could be done.

There are currently approximately 155,000 people employed in the shipbuilding and repair industry [Ref. 9]. The skills required for the GPS installation are available for hire if additional employees were required by the GPS installation program. According to the US Bureau of labor statistics there were 203000 unemployed electrical workers, 142000 unemployed fabricated metal workers, and 79000 unemployed communications and other public utility workers, in December 1983. This unemployed labor pool is large and should be able to provide any employees required by the GPS installations. The problem with mass hires of personnel by shipyards and repair facilities is that as the pool of unemployed labor shrinks the high level of demand may increase the competition for the available labor forces driving wages up. There may be local difficulty with the availability of labor. Although shipyards have historically shown fairly

stable employment patterns in the aggregate, employment at individual yards fluctuates widely depending on the work-load. There are mass hires during high activity periods and mass layoffs as activity slacks. Shipyard workers have also shown an historical reluctance to move, even for guranteed jobs elsewhere. The labor force that is availible in the local area is all that the shipyards have been able the draw upon. This lack of labor mobility could impair an individual shipyards ability to hire workers to install GPS. In the general case a shipyard has the capability to install GPS.

B. PROPOSED PLAN OF ACTION: SHIPYARD INSTALLATION

The installations will not be conducted enmasse because of the adverse impact on national security. Nor would it be sensible to place a ship in a yard facility solely for the installation of GPS. The skills required for the installation of the GPS are available elsewhere. Use of other installation methods would allow the installation to be completed without the incurrance of the significant overhead fees that are incumbent in the maintenance of the large amount of fixed capability required by a shipyard. Navy ships routinely enter shipyards for regular overhaul with most ships scheduled to undergo an overhaul every five years. Adding the installation of GPS to an overhaul would be only a matter of an addition to a contract for overhaul work.

The current estimating figure for shipyard labor and overhead costs are in the range of 30 to 35 dollars per hour. The actual rate will vary depending on the geographic area (affecting labor rates) and the utilization of each facility (affecting overhead). The planning data for the USS Constellation fits into this range. Labor and overhead

rates used for the Constellation planning are 33 dollars per hour. Since the Constellation is part of the testing program its installation is unique. She will receive both of the GPS receiver designs that are currently in competition. Planning data from Supships San Diego estimates that 4330 direct labor hours will be required to install the two systems. Assuming that installation of only one system will entail half of the labor of the dual installation there will be 2165 man hours required. This equates to 84,645 dollars for labor and overhead. Since this installation is part of the testing of GPS rather than an operational installation no learning curve was used.

In addition to labor and overhead the incremental costs of the addition of items to the overhaul package must be considered. The addition of GPS installation will increase the scope of the overhaul contract and may increase the negotiation difficulty. There is also the possibility of increased costs during contract administration. Contract administration cost increases must include any costs that are incurred by the increase in the size of the shipboard internal management system, Ships Force Overhaul Management System (SFOMS). These costs are very difficult to estimate. The installation of GPS is not expected to increase the length of the ROH period. Any increase in the length of the period would entail incurrance of significant additional costs.

C. DIFFICULTIES ASSOCIATED WITH SHIPYARD INSTALLATION.

One of the most serious difficulties with the shipyard installation approach is that the schedule and related funding in POM 86 must be changed. The POM 86 schedule has the installations for all of the ships in a class occuring in one year. This is not how overhauls are scheduled. Most

ships are subject to five year overhaul schedules, this places roughly one fifth of the ships in a class in overhaul during a given year. The current schedule calls for 13 installations in 1989, 1 in 1990, 258 in 1991, 19 in 1992, 52 in 1993, 103 in 1994, 35 in 1995, and 22 in 1996. This does nct reflect the overhaul schedule. Furthermore the installation work is funded by operations and maintenance funds, which are only availible for use during one fiscal year. These funds must be rescheduled to reflect overhaul timing or there will be a large surplus of funds in 1991 and shortages in the other years.

Related to this schedule and funding problem is one of reduced flexibility. The overhaul schedules are driven by factors other than GPS. Since the GPS is not a major scheduling factor in an overhaul any problems with GPS, or related item procurement, could cause the ship not to receive the GPS during the originally planned overhaul. The GPS would then be installed during the next scheduled overhaul for that ship and this would alter the installation schedule dramatically. The installationprocess could not simply be delayed. The order in which ships would receive GPS would change (ie the ships that had been scheduled to receive the system early in the program would receive it near the end), unless of course the installation was slipped five years. The exact order in which the ships receive the GPS receiver in is not such a critical matter that the overhaul method of installation should be rejected solely for this reason.

It is however important that the installations procede smoothly. This is where the overhaul installation plan may cause problems. The contracts for ship overhauls are issued in advance of the overhaul. If the GPS became available after the overhaul contract was issued, but before the scheduled ship went through overhaul, the system might not

be installed. Similarly, if the system became unavailable for installation after the contract was finalized it would require changes to the contract. Any change to a contract takes time and can add to the cost of the contract. It is this lack of flexability that is important and must be considered.

The second problem area is interfacing. There are many repairs, overhauls, or replacements of shipboard electronic systems during overhual. Since the method of interfacing with shipboard equipments is not yet known, the equipments that are required for the interfaces are not yet known. It is probable that the equipment needed for interface will be unavailable for portions of the overhaul, and possible that the equipment would be unavailable for the majority of the period. The equipments that GPS will interface with are often refurbished during overhaul. The refurbishment includes the installation of any required alterations or field changes, and any general maintenance that may be required. This will complicate the scheduling of installation. Once the method of interface is determined, the exact points of interface can be determined and further planning may be done. Regardless of the interface method there should be some time during the overhaul that all required systems are availible.

A third problem is a low learning curve at shipyards. Historically, shipyards have shown lower wages for skilled workers than at other skilled jobs in the same area. These lower wages coupled with the fluctuations in the employment levels have produced turnover rates as high as 75% per annum [Ref. 10]. These high turnover rates reduce any learning curve effect that may have been experienced at a shipyard to nearly zero.

D. ADVANTAGES TO THE OVERHAUL INSTALLATION METHOD

The major problem encountered by the Naval Electronics Systems Engineering Center, San Diego, installation team during the Kitty Hawk installation was the operational schedule. This problem can be completely avoided with a overhaul installation. A ship in overhaul will not be subject to any unscheduled operational requirements. This stability will allow the installation to be conducted in a logical flow, without interruption, and costs held to a minimum. Anytime that work must be stopped and restarted, costs will be increased. This is because workers must secure any partially completed work and remove tools and equipment from the ship. When work recommences all tools and equipment must be set up and the work area reprepared. There is also the danger of workers forgetting items that were not completed before the installation process was interrupted (the author has experienced this problem). These omissions increase the probability of malfunction once the equipment is completely installed. The increased stability of the shipyard environment will improve the ease of the ship check as well. The problems of bulkhead penetrations being utilized for other purposes will be reduced, because there will be less time between ship check and the actual installation.

The shipboard environment during overhaul will also facilitate installation because, the whole crew will be oriented towards industrial work. Fire watches will be readily available. The process of running the cabling will be easier because there will be less traffic through the ship. The members of the ships crew will have no operational requirements to interfere with the support of the installation team.

Installation by personnel employed by the shipyard will eliminate the need for transportation of installation personnel to the location of the installation, as required by some other methods. This can be a significant cost factor in the tiger team installation method. There are also no requirements for per diem. Per diem for an installation team, especially in a high cost area, will be significant. These two expenditures can be totally avoided with a shipyard installation.

The third advantage is the ease of quality assurance inspections. A ship overhaul has many complex components. The existence of the numerous jobs that require a quality assurance normally requires a permanent quality assurance organization for the ship. This organization could conduct the quality assurance work on the GPS installation without the added expense and difficulty that is present in the other installation options.

V. INSTALLATION BY SPECIAL INSTALLATION TEAM

A tiger team is a special team that would conduct the installation of the GPS in a ship. The team would be independent of the ships organization. The team would arrive at a ship install the GPS and then proceed to the next installation site.

A. TEAM ORGANIZATION OPTIONS

There are two questions that must be addressed regarding the organization of a tiger team for GPS installation. The first is what will be the compostion of the team? Will the team be made up of contractor, federal employees, or Navy personnel or will it be a mixture of the three? The second question is how many teams will be formed?

The composition of the teams can have a great effect on the cost of the installation. The cost of the installation is not the only factor to consider in the make up of the installation team. Are there personnel in the Navy who are availible for assignment to an installation team? The Electronics Technician rating is currently manned at 102.5 % [Ref. 11]. This surplus of Electronics Technicians shows the Navy currently has the manpower to form installation tiger teams. It is difficult to predict the exact Navy manning levels in the 1989 through 1996 time frame, however the personnel are avialable now for assignment to a tiger team.

A Navy tiger team should be lead by an Electronics Technician Chief. The assignment of a Chief Petty Officer as the team leader accomplishes two purposes, 1) it provides the necessary technical skill for the installation and 2)

the Chief will be a responsible leader for the team. The team should also have a Hull Technician assigned to perform the required mounting of the equipment and to install any required bulkhead penetrations. An Interior Communicationsman should be assigned to complete interfaces with ship systems such as the gyro and the electromagnetic log. The skill level of these two positions is not as critical as that of the Electronics Technician [Ref. 12]. They will be working under his direction, and performing tasks that will be very similar regardless of the ship that the installation is being performed for. They can also draw on the skills of the ships force to solve any problems encountered. Assignment of Second Class Petty Officers to the team should provide all skills required in these areas.

In contrast, if the team is to be manned solely by civilians the skill levels required for the installation are GS-11 for the Electronics Technician, WG-10 for the Interior Communicationsman, and WG-9 for the welder (GS is a General Schedule Civil Servive employee and the WG is a Wage Grade Civil Service employee). Wages that would be paid to a GS-11 vary from $25,366 to $32,980 per year. Using the standard Civil Service of 260 eight hour days in the work year, this converts to $12.20 to $15.85 per hour. The WG wage levels vary through out the country, and are based on the prevailing local wages. Using the wage scale in effect for the Monterey California area, a WG-10 would receive between $10.51 and $12.27 per hour and a WG-9 would receive between $10.05 and $11.72 per hour. All WG workers are paid by the hour. If set standards are exceeded then they are paid overtime. GS workers are paid on a salary basis.

If the team is to be made up of contractor personnel instead of government employees the wages could vary from the government standard. The cost of a contractor team would be subject to determination under standard contracting

procedures. Since the cost of the contractor team is subject to negiotiation it is difficult to predict the exact wage level that would be paid. The Bureau of Labor Standards reports that non-supervisory metal workers received an average of $8.24 per hour in gross wages, communications workers an average of $11.95 and electronics workers an average of $10.46.

In determining the number of installation teams required there are several considerations that must be used. Using a large number of teams would permit all ships to have GPS installed simultaneously. This approach would necessitate having all GPS receivers available for installation before the process commenced. This is not the most logical method. By matching the installation rate to the rate at which the equipment becomes available (the production rate) the GPS can be introduced into the fleet in the quickest manner, there will be no waiting for more systems. By installing the receivers over a period of time rather than simulaneously the length of time that the work will be available to the work force will be increased. The increased length of the process will make the job of installer more attractive on the job market. More importantly this will allow a learning curve to come into effect. Although all installations will be different in terms of specific detail the overall conditions will be the same. As each member of the tiger team completes more installations the member will become more proficient at the work. This will make the installations that occur later in the process faster than the ones in the begining. Since labor costs are the primary costs in the installation, the later installations will be less expensive. This method of installation is the only one in which the learning curve will come into full effect. In the shipyard envirionment the learning curve is reduced by high turnover rates. A ships force would only conduct one

installation and therefore not benefit from the learning curve.

The learning curve could be used to its fullest extent if all the ships of one class were fitted with the GPS by the same tiger team. This would allow the team to become very familiar with the requirements of a particular class of ship. Using one team to complete all work for each class would fit well with the current schedule, since most classes are scheduled to receive the GPS in a single year.

Scheduling the entire class to recieve the system in one year creates several problems. Ships of the same class are not normally all homeported in the same place. Since the ships will be in several locations there are two alternatives for completing the installation, 1) either the team can go to the ship or 2) the ship can come to the team. Sending the team to the ship is the option normally considered. If each team were to only install GPS on one class of ship there would be massive travel requirements. Not only would the team have to visit each port in which ships of that class were homeported they would have to visit each port several times. This is because ships of the same class do not have identical operating schedules, they will be available in their homeports at different times. The alternative to several visits to each homeport is to have the team travel to where ever the ship is operating.

This would incur very large international travel costs. Travel costs could be reduced by using a single team to install GPS for all ships in a given port. However this would lessen the learning effect that would be gained from having one team conduct all installations for a class, but would not eliminate the entire learning effect. Regardless of the differences between ship classes the GPS installation is similar in all ships. The differences are in equipment locations, cable routing, and equipment that must be

interfaced with. The required wiring, foundation work, and interfacing methods will be the basically the same.

Travel could be even further reduced by establishing six installation centers. Tiger teams located in Norfolk Virginia, Charleston South Carolina, Mayport Florida, Pearl Harbor Hawaii, and in Long Beach and San Diego California, could install approximately 85% of the GPS for Navy surface ships without incurring any travel expense. This percentage is based on homeport assignments in effect in 1984. [Ref. 13], [Ref. 14]. The exact percentages will undoubtably change over time, however these six locations will probably retain the heaviest concentrations of ships. Again with this proposal the ships of one class would not all receive the GPS sequentially, therefore not fully utilizing the learning curve. The loss sustained by not gaining the full benefit of the learning curve is more than offset by the reduction in travel costs and per deim. Ships that are not homeported in these six homeports could have the GPS installed by tiger teams making special visits to other home ports.

Current travel costs are 20.5 cents per mile for civilian workers using private autos. The rates for air travel vary, depending on the airfare to the port location. There is an effort made to utilize the least expensive mode of transportation so in most circumstances the 20.5 cents represents the most expensive option. For civilian workers, the per diem rates range from $23.00 per day to a maximum of $75.00 per day depending on work location.

Another option is where travel and per deim costs could be completely eliminated by establishing a single installation center, and having all ships that are to receive GPS come to that location. The current cost of marine diesel fuel is about 87 cents per gallon. This price is very sensitive to the world oil supply in relation to the demand.

large variations in the cost of fuel will affect this analysis. Marine diesel fuel is used by the majority of Navy non-nuclear powered vessels. The exact rates of consumption for a particular ship are classified and therefore not addressed herein. By using unclassified estimates of comsumption an estimated range of $26.97 to $67.86 per mile can be derived This estimate is based on fuel capacity and range at 20 knots as reported in Janes Fighting Ships. This estimate is probably high because 20 knots is not the most economical speed for most ships. This can be compared with the costs of personnel travel to show that moving a ship is more expensive than moving tiger team. The $26.97 far outweighs the 20.5 cents.

Fuel costs are not the only consideration in moving a fleet unit. The impact on exercise schedules, personnel training, other maintenance, and established leave policies must be considered. The cost of moving a ship becomes unacceptable if a ship is restricted from operational use for an significant period. This would rule out the use of a single installation center. However, if the six centers outlined earlier were to be established only about 15% of the ships would be required to travel to installation centers. This 15% would be even further reduced when ships that are home ported overseas, and required for operations in those overseas areas are exempted. These ships will fall outside the general installation plan because of their important missions.

The most advantageous method for installation with a tiger team is the establishment of six installation teams in the major homeports, and completing installations in other areas via a traveling tiger team. These teams should be manned with Navy personnel to receive the most economical wage rates for the installation teams.

B. PROPOSED PLAN OF ACTION: TIGER TEAM INSTALLATION

The range of wages for a Navy installation team is from $4.56 to $11.54. This figure reflects the military pay scales in effect as of January 1984. Computation of these rates are detailed in chapter six. The composite wage for the Navy installation team will change based on the actual team composition and manning. For the purposes of comparison an average of $7.50 per man hour, midway though the wage range will be used. This wage estimate can be used in the SEESTALL model producing an estimated cost of $70032. The SEESTALL computation is detailed in appendix A. This estimated installation expense is much less than for the shipyard installation method ($70032 vs $169290).

C. DIFFICULTIES ASSOCIATED WITH TIGER TEAM INSTALLATION

There are three major difficulties associated with this approach. They are: travel expense, quality assurance, and the requirement for an operating base.

The tiger team method will require extensive travel for the team. As shown above this travel can be a significant expense. Travel expense can be minimized with six installation centers but, travel will still be required to a greater extent than in the other installation options.

Quality assurance becomes difficult with this approach because it is difficult for a member of the installation team to inspect his own work for accuracy. If this is avoided by having a seperate team member conduct all of the quality assurance inspection what will that person do during the early stages of work? An idle member of the team would be a waste of money. If the inspector were to travel seperatly from the rest of the team then additional travel expense would be incurred. This additional expense would arise from the administrative effort needed to schedule

seperate travel, the probabilty of seperate rental cars, hotel and other expenses. From a quality assurance standpoint it is best to have the inspector travel seperately from the team, and complete the inspection after the complete installation is completed. This would idle the installation team while the inspection was being conducted. The quality assurance inspection could occur after the installation team leaves the ship. This would reduce the waiting time. Minor repairs to the installation could be completed by the inspector. Any major repairs would require the recall of the installation team. The disadvantage of this method is that the feedback from the inspector to the team will be delayed or incomplete. This might cause the installation team to make the same installation error in several installations. Regardless of the final method chosen there would be inefficiencies. There would be extra travel expenses or idle labor forces, both costing extra money.

A third difficulty with the tiger team approach is that the team will require an operating base. There must be buildings out of which the tiger teams could work. The base would provide storage for test equipment and equipment due to be installed in the near future. Cost of this facility would vary depending on the area of the country. A base of operations would not be required with the other installation methods, shipyards would use their own facilities and ships force would use ships spaces.

D. ADVANTAGES OF THE TIGER TEAM INSTALLATION

One of the prime advantages of this method is its flexibility. A tiger team, regardless of its composition can easily accommodate a change in schedule. This is so because the team would be moving from ship to ship to conduct the

installations so a change in the order will just mean that the next installation would be a different ship than planned. If the next ship is of a different class than the one that had been planned, then there might be a delay while the required cabling and connectors were shipped from storage. If the substituted installation was in a different location there could be a delay while the installation team and the GPS receiver were moved to the new location. This delay could most likely be short enough to be insignificant provided that the required hardware for the installation was available. If the hardware was not available the delay would become significant as the waiting time for the hardware grew. This flexibility gives the Navy a method to meet a changing environment. The flexibility of this method of installation must not be abused by allowing individual commander's desires to drive the installation order, thereby increasing the delays and therefore the cost. The need for rescheduling can be minimized by careful initial schedule planning.

The needs of the Navy and the individual commanders could possibly be better served by this method because it allows the installations to be conducted in a priority manner rather than in the order that ships come due for overhauls. The priorities for the installation should be set by the Fleet Commanders, based on the operational requirements expected for each ship.

The most significant advantage with the tiger team installation method is the benefits of the learning curve. As each team conducts more installations their proficiency and speed will increase. The less time that is spent to complete an installation the less costly it will be. The learning curve is not evidenced in either of the other installation options.

VI. INSTALLATION BY SHIPS FORCE

A. CAPABILITY

The installation capability of a particular ship will vary with the current manning of the ship. Each ship's manning allowance is structured for the configuration of the ship. Then the actual number of people assigned to a ship is adjusted to reflect that ships fair share of the manpower available to the entire Navy. A ship's fair share will vary over time as the manning levels change in the Navy.

Not only does the ships manning level vary over time but the skill levels will vary as well. The billets aboard a particular ship are filled in accordance with Navy personnel policies. These policies attempt to ensure that each ship has the skills required to fulfill its mission. As in any policy employed this is not 100% sucessful. There will be people assigned to ships whose skills are deficient. Replacement of these personnel is possible, however, it requires a significant effort and patience (time). This potential lack of skill could be critical in the GPS installation. A ship does not always have the manpower base to draw from that a shipyard or a tiger team has. The ship must install the equipment with the skills currently available or seek help from other sources. The option of hiring another person who has the required skills is not available to a ship. (A tiger team or a shipyard is not restricted in hiring ability as long as the required skill is available in the labor market.) If a ship is faced with a lack of the required skills assistance can be requested from an Intermediate Maintenance Activity (IMA). An IMA is a shore activity with the mission of assisting in repair and

maintenance of ships. There are IMA facilities located in most major homeports.

Most ships could install the GPS with the personnel that are part of the crew. However some ships may have to receive assistance from an intermediate maintenance facility, but this help is readily availible. The GPS can be readily installed by this method.

B. COSTS ASSOCIATED WITH SHIPS FORCE INSTALLATION

The most difficult question in this area is: Should the labor of the ships personnel be costed?

The argument for not costing the labor is that there is no additional cost to the Navy. The workers, whether assigned to a ship or an intermediate maintenance facility, are Navy personnel and must be paid regardless of what work they accomplish.

The argument for costing the labor is that there is an opportunity cost of using these workers for the GPS installation. If the GPS installation was conducted by someone other than ships force,the ships force would have been utilized for other work. That work may have used the skills required by the GPS installation or it could have been unskilled labor performed by the skilled workers. The work that they would have done most likely will still have to be completed. This can be accomplished in several ways. The working hours of the installation personnel can be increased or the work can be assigned to other personnel. Either method will increase someone's workload and therefore morale could be affected. The GPS installation process is fairly short, an estimated 30 days for a carrier [Ref. 15], therefore this effect should be small. If any work is rescheduled to accommodate the GPS installation there could be effects on other areas of the ship. There may be wasted manhours

spent waiting for a job to be accomplished by a GPS installer, for example a welding job. The scheduled maintenance of electronic equipment would have to be rescheduled while electronics technicians perform the GPS installation. This rescheduling could affect the readiness of the ship, especially in the areas of communications and sensors (radars). It could also affect the ship in more mundane areas, such as the Planned Maintenance System (PMS). The PMS is the way that all required preventive maintenance is scheduled aboard Navy ships. Any maintenance that is not completed within the required time period is considered not to have been completed. This noncompletion can adversely affect the ship grade in a PMS inspection. This inspection is periodically required, and a certain grade is needed for the ship to qualify for various warfare area awards (such as the Battle Efficiency Award).

If assistance is received from an IMA should this labor be costed? An IMA has a seperate budget from the ship. Any work done by the IMA must be completed under that budget. For the IMA records the labor will be charged to a particular ship, should that charge be reflected in the cost of the GPS installation? The IMA could accomplish other repair work for that ship or for others instead of working with the GPS installation, so again the opportunity cost argument exists.

Since the workers who install the GPS would not be idle if the installation was conducted by a method other than ships force it is the opinion of the author that the labor should be costed. Additionally not costing the labor would present a false impression. Since the amount of support equipment required for the installation is minimal most of the installation costs are derived from labor. By not costing the labor for one installation method the costs would not truely represent the situation.

C. PROPOSED PLAN OF ACTION: SHIPS FORCE INSTALLATION

The ships force installation team will include the same skills as the other proposed teams. To determine the makeup of this team it is necessary to convert civil service standards tc Navy ratings and paygrades. Using the civil service qualification standards a rough conversion can be made. The standard for an Electronics Technician [Ref. 16] requires that a technician GS-8 and above haves six years of total experience. Of these years two are of general experience and four are specialized. One year of the specialized experience must be directly related to the position being filled. These requirements are met by a Chief Electronics Technician. The range of monthly wages for a Chief Electronics Technician is from $1255.50 to $1851.00 depending upon his or her years in the Navy. These wages do not include a sea pay bonus or any other special allowances such as the basic allowance for quarters. Qualification for these allowances is dependant upon the person in question. Because these allowances will vary depending on the actual installer they will be omitted here. Only sea pay of $150.00 (the basic rate) will be included, by virtue of being assigned to a ship the servicemember will qualify for at least this amcunt. Using the same approach, the skill level required for the welder and the interior communications specialist are approximately that of a Petty Officer Second Class. Basic wages for these personnel range from $791.10 to $1146.90 per month depending on length of service. These wages, reduced to an hourly level, are in the range of $4.56 tc $11.54 per hour, based on the pay scale in effect on 1 January 1984. The hourly rates were computed on the basis of the standard Civil Service work year of 260 eight hour days. This standard most likely is conservative for the actual work hours of Navy personnel.

The standard does provide a basis for comparison. These rates are less than one half of the wage and overhead rate for a shipyard installation, consequently this method is much cheaper.

D. DIFFICULTIES WITH SHIPS FORCE INSTALLATION

The major difficulty with this method is the availability of the proper skills in the ships crew. As skill levels vary so might the quality of the installation. If any alterations were made in the installation plans, because of the lack of skills or for expediency it would be difficult for future repairs or improvements to be made to the system. The GPS could develop into a system that works fine while the members of the installation team are still onboard, but fails as soon as they leave because they take the knowledge about all of the special modifications that were made during the installation process with themselves.

Related to the range of skills that would be used to install the system is quality assurance. Installation by a variety of people in all Navy ships would create a very difficult quality assurance problem. The only way to insure quality is maintained is to have all installations inspected by someone not assigned to the ship. The reason that the inspection must be conducted by someone not from the ship is that it is most likely that all shipboard technicians will be involved in the installation effort, and it is usually not as effective for a person to inspect his own work. If there are errors in judgement during the installation they might not be discovered by the person who made the judgements. If an offship quality inspector is used then the problems experienced by tiger teams with travel and per deim will be introduced to the ships force installation method.

A second significant difficulty is the proper installation of the antenna to preclude any EMI. This problem grows with the complexity of the electronic suite of the ship, the more electronic equipment a ship has the more difficult it is to place the GPS antenna so that it is not interfered with. This problem can not be circumvented by using more detailed instructions in the installation plans. There are many differences between ships, even ships of the same class, and not all differences are properly reflected on the blueprints. If the antenna is not properly placed then it will not be able to receive the satellite signal and no navigational information will be provided.

The problem of delivery of the GPS equipment to the ship is also important. The equipment should be delivered to the ship when there is time in the ships schedule to install it. If the equipment is delivered during a period that heavy demands are being placed on a ship it is possible that the GPS installation would be delayed until the operational requirements are met. If the installation was delayed the possibility of lost parts becomes a problem. It would be easy for parts of the installation kit to be lost before installation. Since there are many long lead time procurement items in the package it is possible that the loss of a single piece could force significant delays on the completion of the installation. A maintenance availibility would probably provide the best environment for installation. The ship will be more oriented towards repair work, and there will be fewer conflicting demands placed on the crew. Training availabilities should be avoided because many of the ships company will be at schools and not availible for work. Free time in the operational schedule of most ships is short and rare, so the delivery schedules would have to be closely matched with the operational schedule of the ships.

E. ADVANTAGES TO INSTALLATION BY SHIPS FORCE

This method has several advantages. The most obvious is the reduced cost. This method can provide the installation at a cheaper rate per ship than either of the other methods. The other advantages are schedule related. This method allows the installations to be conducted in accordance with the PCM 86 schedule. If ships are deployed installations could still be accomplished, as long as the equipment could be shipped to the ship. This method also allows the schedule to be modified to fit any changing priorities. If the installation priorities were changed there would be no effect or learning since ships force does not experience a learning curve.

VII. CONCLUSIONS

The purpose of this thesis is to examine the various alternatives for the installation of the NAVSTAR Global Positioning System in surface ships of the US Navy. The goal is to find the method that completes the installation in both a timely and an efficient manner. Some ships will not follow the standard installation plan because of their unique and high priorities. Ships such as fleet flagships homeported overseas will have the GPS installed in the quickest manner, even if the quickest manner is not the most logical for the entire fleet.

The examination of the alternatives lead to three possible methods for the installation of the GPS receiver in surface ships. Installation: 1) During a ships regularly scheduled overhaul, 2) using a special installation or tiger team, or, 3) using the skills availible in the ship's force.

The choice of the installation method will not only affect installation costs, but several other items as well. The rate that the chosen installation method will introduce the GPS to the fleet should be coordinated with decisions made regarding the production rate for the receiver system. The rate that the GPS is introduced to the fleet will also affect the funding profile required for training maintenance technicians. If the system is introduced slowly then initially there will be a small demand for technicians, if the system is introduced quickly the demand for technicians will have a sudden impact on the funding profile.

Each of the alternative installation methods can support differing installation rates. The ships force and tiger teams can support wide ranges, however if the number of installations drops below about 12 per year the workload

will not be sufficient to support a tiger team. The shipyard installation rate is governed by the rate that ships enter overhaul. Since the majority of ships operate under a five year overhaul schedule there will be about 100 installations per year.

A. SUMMARY

There is no single best alternative. Each of the three methods investigated in this thesis have their own advantages.

Regardless of the method chosen there will be problems with the current installation schedule. The current schedule is based on completing the GPS installation for an entire class of ships within one year. This method is feasible for small classes of ships but becomes more difficult as the number of ships involved grows. In devising the the final schedule, things such as the various homeports and operating schedules of each ship class must be considered. For example, it will be difficult to install GPS on all ships in a class, such as the DD-963 class, in one year. The DD-963 class ships are homeported in five different places on both coasts of the United States. Not only are the ships spread over several homeports, but they are subject to a variety of operating schedules, with ships in the Mediterreanean Sea, the Atlantic Ocean, the Indian Ocean, and the Pacific Ocean at any one time. The coordination needed to install the GPS in these ships in a single year is very difficult.

A schedule that fits all three installation methods is difficult to derive, because of the differing rates of installation that the three alternatives can support. The only type of schedule that could be common to all three methods would be the overhaul schedule. The overhaul

schedule dictates the installation schedule for that method and the other two methods have the flexibility to conform to the overhaul schedule. The best scheduling method is to select the installation method, aware of the effects that each method will have on the installation schedule, then construct the schedule. Regardless of the schedule that is chosen the current funding profile, reflected in POM 86, must be altered to support the chosen schedule. Since the installation of the GPS is scheduled to begin in 1989 the funding requirements must be made known in sufficient time to be included in the POM for 1989. The installation is funded with operations and maintenance funds so the POM must be modified no later than 1988 to ensure funds are available.

Preplanned Product Improvement plans should have minimal effect on the installation method choice. Any improvements should primarily affect the internal operation of the receiver. Improvements may have an effect on the required interfaces, however, any change in the interfaces would primarily affect wiring of the installation not the basic installation method.

Utilizing ships force skills is the least expensive method of installation. This method also allows great schedule flexability, conceptually all ships could receive the GPS in a single year, or the installation could be spread over many years, without a large effect on the installation costs. This method will complete the installation of the GPS in a timely and economical manner initially. However, this advantage is outweighed by the problem of quality assurance. The range of quality that would result from this installation method is unacceptable. The wide ranges of skill levels reflected in shipboard technicians, and specifically the lead technician, would produce wide ranges in the in the quality of the installations. The

quality assurance work could be done by a quality assurance tiger team. A tiger team would introduce the disadvantage of travel costs to the ships force installation method, but it would guarantee better quality. The Naval Electronics Systems Engineering Center installation personnel feel that the ships force approach will create enough quality problems that the quality assurance tiger team would be forced to do a significant amoumt of rework. The author concurs with their position, that this option is unacceptable. [Ref. 17].

The tiger team method of installation allows a high degree of flexibility. However, this method is restrained by the large travel costs that will be incurred for movement of the tiger teams to the installation site. These travel costs can be greatly reduced by creating six installation centers in the major ship homeports. Creation of six installation centers would place a center in the homeports of 85% of the Navy surface ships. The creation of these installation centers will reduce the travel costs for the tiger teams but it will increase the costs that must be incurred to support the team. If a team is established with a fixed base of operations it will require buildings out of which to conduct operations and places to store test equipment while no installations are in progress. The tiger team installation option can conduct the installations in the least amount of time.

Installation during regular overhaul is the most expensive. This is because the labor and overhead rates for a shipyard reflect the availability of a large amount of fixed capability, such as: building ways, machine shops, and extensive support facilities. These facilities are not used by the GPS installation, however, they are used by the ship during an overhaul. The overhead due to these extensive facilities is allocated on the base of direct labor hours.

It is because of these allocated costs that the installation of the GPS during overhaul is more expensive.

Installation in a shipyard would overcome many of the difficulties of the other methods. For example, travel would be eliminated, work would be performed by shipyard employees, Quality Assurance work would be performed by the personnel assigned to the Supships Quality Assurance personnel assigned to the particular ship in overhaul.

The primary disadvantage to this method is the inflexability of the schedule. Ship overhauls are scheduled as part of the ships operational schedule, and GPS must conform to the scheduled times or the system cannot be installed during overhaul. This lack of flexibility is not totally a disadvantage. A fixed overhaul schedule provides stability to the installation schedule. The only schedule changes that will occur are those required by the operational posture of the Navy. There will be no changes of the installation order merely to reflect a desire of one unit Commander to have GPS before another unit. The schedule is prepared in advance by the Atlantic Fleet and Pacific Fleet Commanders, eliminating any need for the GPS program Office to prepare a workable schedule, as would be required by the other installation methods. This installation schedule will only reflect the overhaul schedule, and not any uniquely GPS driven items. The overhaul method will take more time to introduce GPS to the fleet.

B. RECOMENDATION

The basic question is: what is more important? A simple fixed schedule, minimum cost, installation quality, or the impact on the production schedule? In the authors opinion the installation method must be selected on the basis of, highest quality, ship availibility, impact on the production rate, and cost.

The number of GPS receivers that will be installed on surface ships is small compared to the total numbers of receivers that will be procured, therefore the impact on the production schedule is fairly small.

The shipyard installation method will provide an assurance of high quality work, and a stable installation schedule for the GPS. The shipyard environment also assures ship availibility. The higher cost due to the allocation of overhead is offset to an extent by the large reduction in travel requirements. Because of these advantages the author recommends the regular overhaul method for the installation of the NAVSTAR Global Positioning System in US Navy surface ships.

APPENDIX A
SEESTAIL COST ESTIMATING MODEL

The SEESTALL model computes an estimate of the costs for all phases of a shipboard GPS installation. Many of these costs are outside the scope of this thesis, therefore, only the portion of the model that deals with installation costs is addressed. The entire model is included in reference 2.

This computation using the SEESTALL model is for the installation of GPS in the USS Constellation. This computation assumes that the ship is homeported in the same location as the tiger team. This assumption is made because the shipyard estimates that this SEESTALL estimate will be compared with does not include any travel expenses.

The labor portion of the model is detailed here:

Labor

a. Number of foundations:

installed	14	x	16	MH	=	840
removed	0	x	16	MH	=	0
relocated	0	x	32	MH	=	0

Number of shelves:

installed	60	x	2	MH	=	120
removed	0	x	2	MH	=	0
relocated	2	x	4	MH	=	8

Number of LRUs (including antennas at deck level)

installed	19	x	2	MH	=	38
removed	0	x	2	MH	=	0
relocated	0	x	4	MH	=	0

subtotal 998

b. Major antenna runs

to different locations	1	x	3	=	3
to same location	6	x	1	=	6

Major cable runs

to different locations 1 x 2 = 2

to same location 2 x 1 = 2

Minor cable runs

to different locations 69 x 1 = 69

to same location 0 x.25= 0

Number of cables requiring

EMI/grounding 79 x 1 = 79

subtotal 148 x 8 = 1184

c. Number of pressure watertight penetrations

penetrations through

special alloy material 0 x16 = 0

secure penetration 48 x 4 = 192

other penetration 0 x 2 = 0

subtotal 192

d. Number of RF cables 7 x 2 = 14

Multiconductor cable 0 x 6 = 0

subtotal 14

e. Number of antennas or LRUs installed

at mast level 7 x 8 = 56

subtotal 56

f. (number of cables 79 + number of LRUs

installed removed or relocated 26) x 1 = 105

number of LRUs installed 26 x 10 = 260

number of LRUs interfaced 26 x 4 = 104

subtotal 474

a+b+c+d+e+f= 2918 x labor rate (\$7.50) x z

z= 1.6 x (number mast installed antennas)

z= 1.6 x 2 = 3.2 installation cost = 2918 x 7.5 x 3.2 = \$70,032.00

Information utilized in this calculation was provided by K Gugginsburg of the ARCWELL Corporation of San Diego California. The ARCWELL Corporation is a subcontractor to the MDS Company for the USS Constellation GPS installation.

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